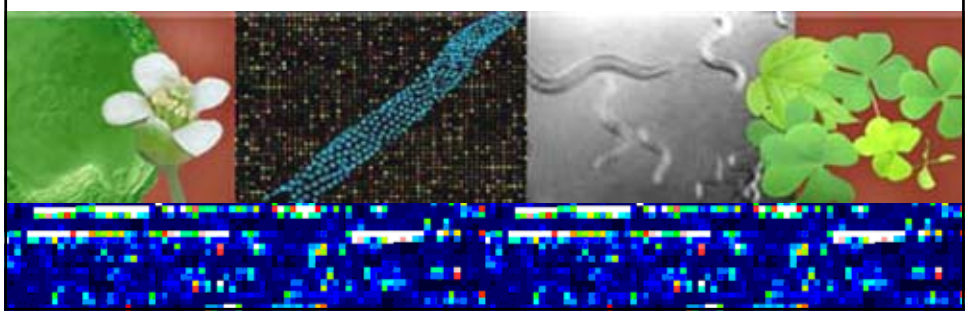
Professor Charles Spillane

**Head of Botany and Plant Science,
NUI Galway**

**SFI Investigator,
Genetics & Biotechnology Lab**

BT217 Lecture 6: Economic Botany



What is Economic Botany?

study of relationships between plants and people.

Study plants economically important to people (plants that are sources of food, fibers, medicines, gums, insecticides, etc)

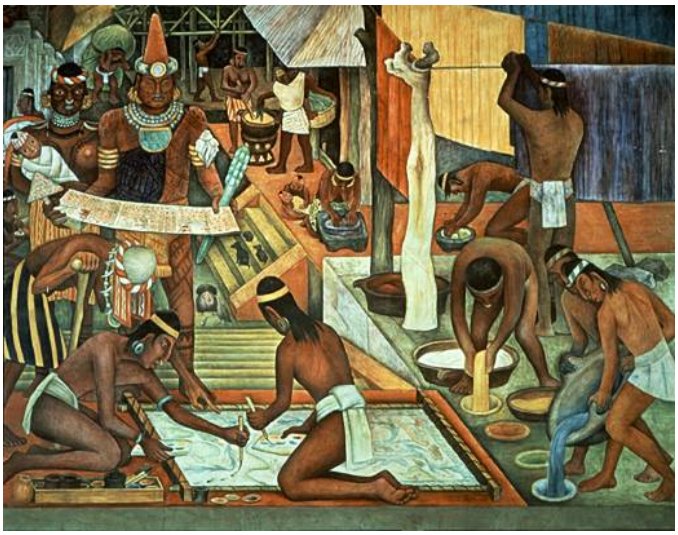
Inter-disciplinary area of study e.g. ethnobotany, anthropology, ethnopharmacology, etc

link between botany and anthropology explores the ways different human human cultures use plants for food, shelter, medicines, textiles, etc

Different human cultures develop different uses for plants

Plants & Human Cultures

Use of plants by past cultures



Diego Rivera

Botany and Plant Science Specialities

Economic Botany

Plants with commercial importance including the study of harmful and beneficial plants and plant products including; coffee, tea, rubber, chocolate…….

Botany and Plant Science Specialities

Ethnobotany

The use of plants by different cultures (e.g. indigenous peoples) as foods, fibres, fuel, medicine, perfumes, dyes, beverages, lumber, paper, textiles…….

Richard Schultes with Yukuna Dancers

1952, Rio Guacaya, Bolivia

“The Plants of the Gods”

Crop domestication

Crop diversity

Cultural diversity

Are all inter-related!

Old World Crops

- **Chinese-Japanese Centre**
  - 6000 BP (BEFORE PRESENT)
  - buckwheat *Fagopyrum esculentum*
  - Millet *Panicum* spp.
  - Soybean *Glycine max*
  - Legumes
  - Citrus
- **Indonesian**
  - 12000 BP
  - Banana *Musa* spp.
  - breadfruit *Artocarpus communis*
  - clove *Caryophyllus aromaticus*
  - pepper *Piper nigrum*
  - coconut *Cocos nucifera*
  - yam *Dioscorea* spp.
  - rice *Oryza* spp.
  - sugar cane *Saccharum officinarum*

Old World Crops

- **Hindustani**
  - 4000 BP
  - cotton Gossypium arboreum
  - bamboo *Bambusa* spp.
  - mango *Mangifera indica*
  - taro *Colocasia antiquorum*
  - cucumber *Cucumis sativa*
  - banana *Musa* spp.
  - rice *Oryza sativa*
  - gram *Phaseolus muingo*
  - pepper *Piper* spp.
  - sesame *Sesamum indicum*
  - hemp *Cannabis indica*
  - kenaf *Hibiscus cannabicus*
  - safflower *Carthamus tinctorus*
- **Southwest Asia**
  - 7000 BP
  - pistachio *Pistacia vera*
  - apricot *Prunus armeniaca*
  - almond *Amygdalus communis*
  - onion *Allium cepa*
  - garlic *Allium sativum*
  - carrot *Daucus carota*
  - vetch *Lathyrus sativus*
  - flax *Linum usitatissimum*
  - pea *Pisium sativum*
  - spinach *Spinacea oleraceae*
  - fava bean *Vicia faba*

Old World Crops

- **Near East**
  - 11000 BP
  - wheat *Triticum* spp.
  - rye *Secale* spp.
  - kole *Brassica oleracea*
  - fig *Ficus carica*
  - barley *Hordeum vulgare*
  - lentil *Lens esculenta*
  - alfalfa *Medicago sativa*
  - pomegranate *Punica granatum*
  - vetch *Vicia sativa*
  - grape *Vitis vinifera*
- **Mediterranean**
  - 7500 BP
  - olive *Olea europea*
  - oats *Avena* spp.
  - beet *Beta vulgaris*
  - hops *Humulus lupulus*
  - clover *Trifolium* spp.
  - grape *Vitis vinifera*
- **Australian**
  - Tobacco *Nicotiana debbneyi*
  - Tobacco *Nicotiana goodspeedii*
  - gum *Eucalyptus* spp.

Old World Crops

- **African**
  - 6000 BP
  - coffee *Coffea* spp.
  - melons *Cucumis* spp.
  - cotton *Gossipium* spp.
  - banana *Ensete ventricosum*
  - rice *Oryza* spp.
  - millet *Pennisetum* spp.
  - date palm *Phoenix* spp.
  - castor bean *Ricinus communis*
  - sesame *Sesamum indicum*
  - millet *Setaria* spp.
  - sorghum *Sorghum bicolor*
- **European Siberian**
  - kale *Brassica oleracea*
  - chicorie *Chicorium* spp.
  - digitalis *Digitaria sanguinalis*
  - strawberry *Fragaria* spp.
  - lettuce *Lactuca sativa*
  - hops *Humulus lupulus*
  - lucern *Medicago* spp.
  - currant *Ribes* spp.
  - raspberry *Rubus* spp.
  - clover *Trifolium* spp.

New World Crops

- **Andean**
  - 8000 BP
  - oca *Oxalis tuberosa*
  - potato *Solanum* spp.
  - ulluca *Ullucus tuberoses*
  - papaya *Carica* spp.
  - amaranth *Amaranthus* spp.
  - pineapple *Ananas comusus*
  - peanut *Arachis hypogaea*
  - chili *Capsicum* spp.
  - quinoa *Chenopodium quinoa*
  - cotton *Gossypium barbadense*
  - rubber *Hevea brasiliensis*
  - tomato *Lycopersicum* spp.
  - manioc *Manihot esculenta*

- **Mexico and Central America**
  - 9000 BP
  - mays *Zea mays*
  - agave *Agave* spp.
  - cashew *Anacardium occidentale*
  - chilis *Capsicum* spp.
  - gourds *Cucurbita* spp.
  - cotton *Gossypium* spp.
  - sweet potato *Ipomoea batates*
  - beans *Phaseolus* spp.
  - cocoa *Theobroma cacao*

New World Crops

- **North American**
  - strawberry *Fragaria virginiana*
  - sunflower *Helianthus* spp.
  - plum *Prunus* spp.
  - raspberry *Rubus* spp.
  - blueberry *Vaccinium* spp.
  - grapes *Vitis* spp.

- Development of New Crops from Prairie and Woodland Plants
- For example: breeding of perennial grains from native grasses, testing of new legumes (*Cassia marilandica*), commercialization of pawpaws

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Food crops

Cereals

Wheat (Triticum)
Rice (Oryza)
Maize (Zea)
Barley (Hordeum)
Sorghum (Sorghum)
Millet (Pennisetum)
Oats (Avena)
Rye (Secale)
Triticale
Fonio (Digitaria)
Canary seed (Phalaris)
Teff (Eragostris)

Sorghum – a staple crop for 500 million people

30 countries

Africa, India, China

Matures in less than 75 days

Highly photosynthetically Efficient

Used for food and beverages

Durra (Africa)
Milo (Central America)
Kaolang (China)

Pearl millet (*Pennisetum glaucum*)

Low yield

Drought tolerant

More nutritions than sorghum

Used as staple food

Labour intensive (weeding etc)

Finger millet (*Eleusine coracana*)

Fonio (*Digitaria*) millets grown In West Africa

Tef (*Eragrostis tef*)

Cultivated in Ethiopian highlands

Excellent nutritional profile
(high in fibre, iron, protein, calcium)

Used to make injera in Ethiopia & Eritrea

Legumes

- ***Ca*. 18,000 known species**
- **Dicots**
- **Distinctive flowers and pods**
  - **Seeds rich in oil (up to ca. 50%) and protein (e.g., 15-50%)**
  - **Flowers are bilaterally symmetrical**

Legumes – uses by humans

Foods
- peas
- peanuts
- soybeans
- kidney & pinto beans
- green beans
- fava beans
- lima beans
- chick-peas (Garbanzo beans)
- black-eyed peas
- lentils

Forage
- alfalfa
- red clover
- white clover
- sweet clovers
- vetches
- cowpeas

Trees
- mesquite
- locust (honey & black)
- mimosa

Agroforestry

- **Leguminous trees are key agroforestry species.**
- ***Albizzia alba* maintains its green growth through the dry season in *Burkina faso,* providing fodder for livestock; the residues in the foreground are of millet which is grown during the rainy season.**
- ***Leucaena leucocephala* in the Philippines: these trees, less than 2 years old, will be cut to provide firewood.**

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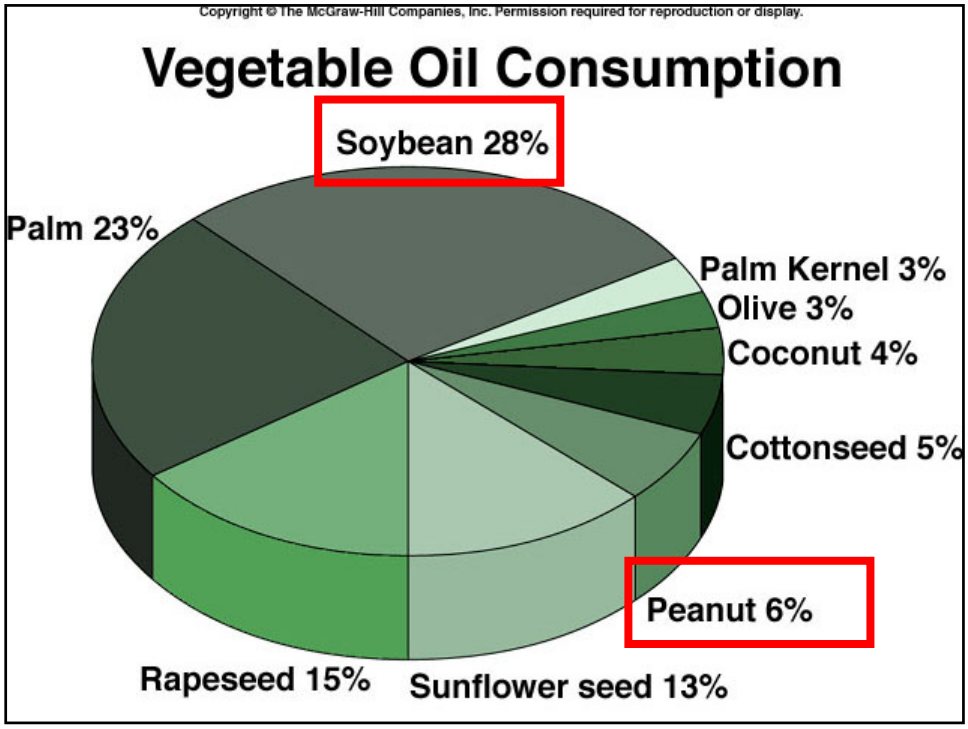

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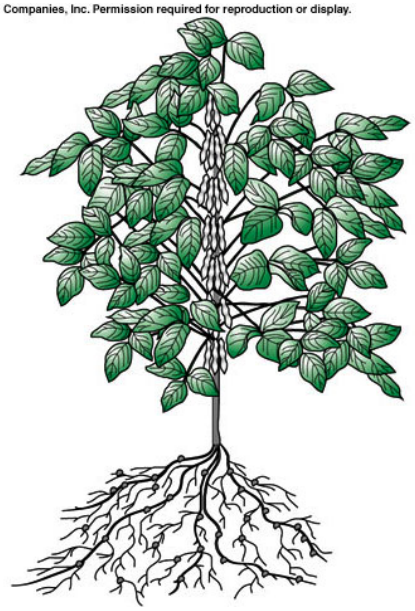
Soybean Plant



- Oil
- Fodder
- Flour
- Soya-milk
- Soy sauce
- Tofu
- Tempeh
- Miso

Soy phytoestrogens

- **Lower cholesterol levels, especially LDL**
- **Lower blood pressure**
- **Reduce risk of breast and prostate cancer**
- **Reduce symptoms of menopause & risks of osteoporosis**

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Alfalfa

Green manures

Cover crops

Above: Red clover growing amongst corn stubble, in early June. The clover was under-sown into the corn crop the previous year (below).

Cover crop

- Suppresses weed growth
- Reduces erosion

Green manure

- Plowed under instead of harvested
- Enhance soil fertility

Oilseed crops

Many families of oil seed crops

Selected/bred for oil content & profiles in seeds

- Cooking oil / margarine
- Condiments (mustards – high glucosinolates)
- Animal feed
- Industrial uses (lubricants, etc)
- Candlewax, soap (Tallowtree seeds)
- Drying oils, varnishes (Tung nuts)
- Stearin, olein from Karite nuts
- Liquid biofuels

Castor bean

Purgative

Non-drying oil

Flax seed

Linseed oil (unsaturated oil)

Used in paint industry

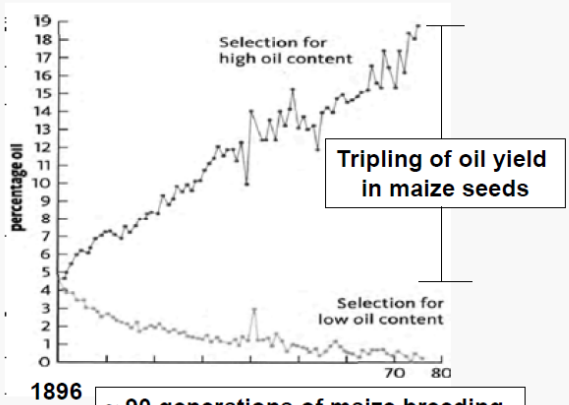
Linoleum

Types of unsaturated oils (fats)

- **monounsaturated fats**
  - one double bond
  - usually from olive oil, almonds, pecans, cashews, peanuts, and avocados
  - does not negatively impact cholesterol levels

- **polyunsaturated fats**
  - numerous double bonds
  - includes vegetable oils (linseed and tung) and fish oils
  - excessive intake may lower HDL (good kind of cholesterol)

Genetics: Plant breeding to develop genetically tailored crop varieties



Tripling of oil yield in maize seeds

1896

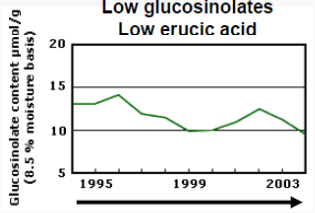
~ 90 generations of maize breeding

Oilseed rape (Canada)

Canadian, low acid oil

Canola

Low glucosinolates
Low erucic acid



New varieties with reduced toxicity

Conventional plant breeding to market (farmer, consumer) timescales are long.

Breeding → Advanced trials → Seed multiplication/certification → Crops in ground

What about plant oils?

Ethanol not an ideal energy vector (energy density low)

	Energy density (MJ/L)	Energy per CO_2 (MJ/kg)
Ethanol	18.4-21.2	12.2-14.0
Methane	23-23.3	20-20.3
Butanol	29.2	15.2
Biodiesel	33.3-35.7	13.3
Hydrogen	8.5-10.1	
Petrol	32-34.8	13.6-14.6
Diesel	40.3	14.2

Oilseed crop yields?

Oil yields	Litres/ha-yr
Soybean	400
Sunflower	800
Canola	1,600
Jatropha	2,000
Palm oil	6,000
Microalgae*	40,000

** Maximum potential for Arizona (USA)*

3º Beyond oilseeds => Oils in non-seed tissues?

Increase energy density of harvested biomass via oil production

Metabolic re-engineering of oil biosynthesis pathways in crops

Oil production in roots of transgenic rutabago (swede)

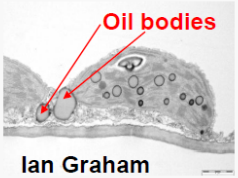
GLBRC
Great Lakes Bioenergy Research Center

Christoph Benning (MSU)

Blocking fatty acid breakdown during leaf senescence => oil accumulation in leaves

⇒ Get this to happen in genetically modified crop before/after harvest?

If silage from forage grasses was 10% oil?



Ian Graham
(Uni of York)

CNAP

Root & tuber crops

From four families

Solanaceae (Potato – Solanum)

Euphorbiaceae (Cassava – Manihot)

Convulaceae (Sweet potato – Ipomoea)

Dioscoreaceae
- **Yams – Cocoyam**
- **Taro – Colocasia**
- **Yautia - Xanthosoma**

Vegetables

Fruits and nuts

Herbs and spices

Sugar crops

Sugar has had major impact on humanity

Sugar trade – slavery – human health

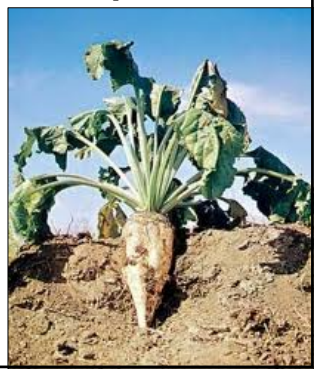
Sugar beet – new source of sucrose

Naval blockades of France in 1700s-1800s => sugar trade disrupted

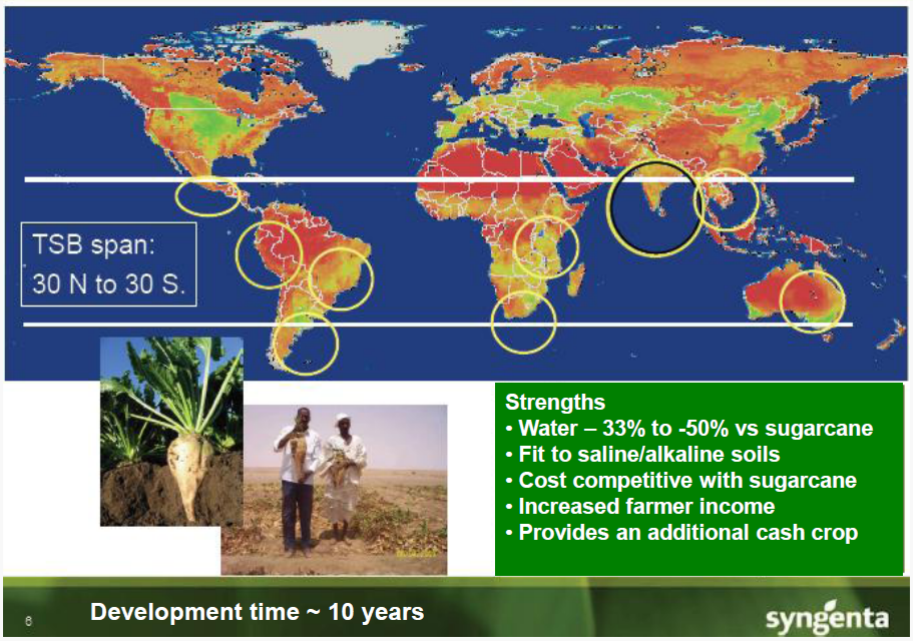
New source of sugar needed (Napoleon)

1747 – chemist Marggraf found 4% sugar in beet

4% → 6% → 20% sugar content

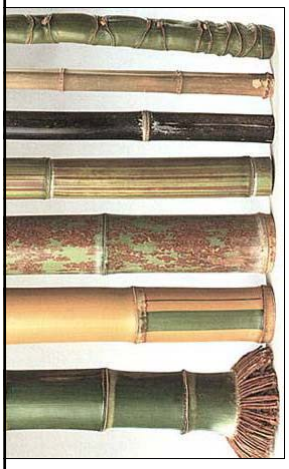


Tropical sugar beet – a new bioenergy crop


TSB span:
30 N to 30 S.
Strengths
• Water – 33% to -50% vs sugarcane
• Fit to saline/alkaline soils
• Cost competitive with sugarcane
• Increased farmer income
• Provides an additional cash crop
Development time ~ 10 years
syngenta

Plants as structural materials

Bamboo & rattan



Most fabrics & textiles made from plants

Fibers – History

• 10,000 yrs ago – linen (from *Linum*) in Turkey

• Use of plant fibers predates that of animal fibers

8,000 yrs ago – fiber sandals in Missouri
7,000 yrs ago – sheep domesticated
5,400 yrs ago – cotton fibers used in Mexico
5,000 yrs ago – silk in Asia

Plant vs. Animal Fibers

Plant fibers:

- composed – partly - of cellulose
- can be heated
- hard to dye
- attacked by fungi, mold, termites
- less elastic but more absorbent of water

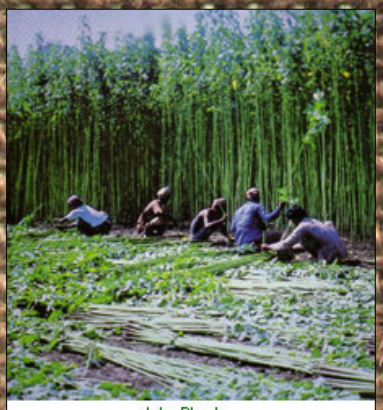
Animal fibers:

- composed of protein molecules
- denatured by heat / brittle
- readily accept dyes
- attacked by moths, silverfish
- more elastic, less absorbent of water

Fibres from plant stems (bast)

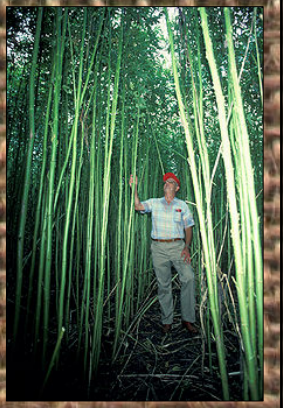
flax

jute



Jute Plant

kenaf



Fibres from leaves

Sisal (*Agave sisalana*) leaves

Central America

Sisal used for ropes & twines

Fibres from plant seeds

Cotton is a major crop worldwide

Cotton fibres (hairs) are unicellular trichomes

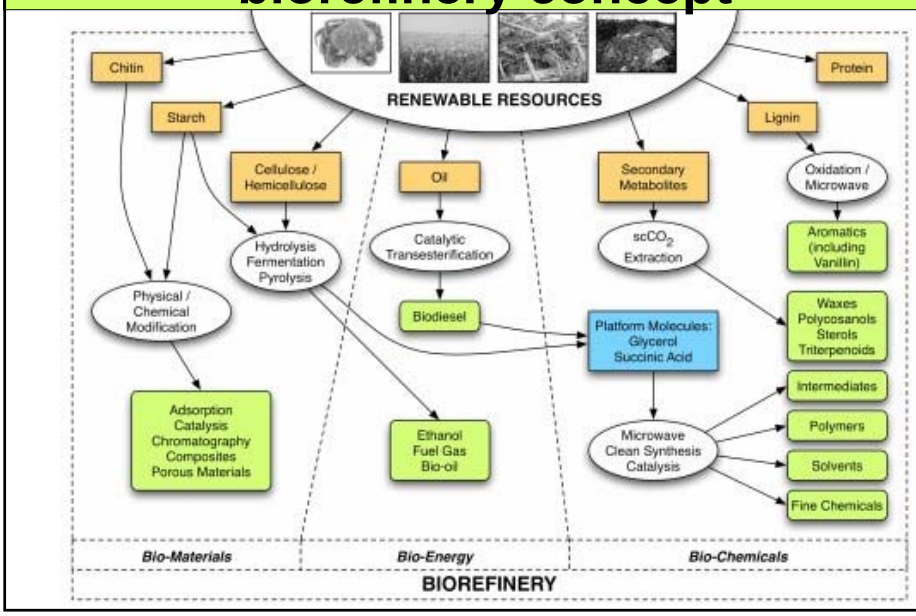
Coir from coconut seeds

Turpentines, gums, industrial chemicals

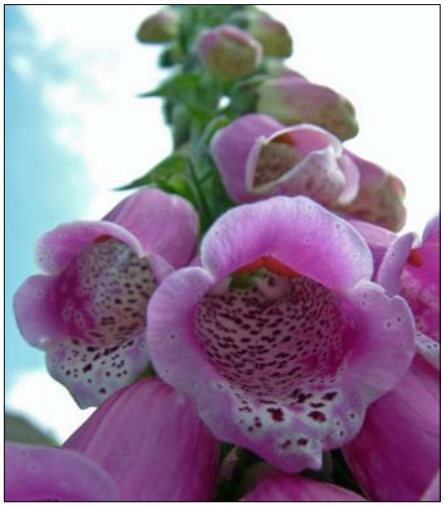
Volatile oils of pine trees
Used as paint thinner/varnishes
Also non volatile resins (rosin)

Gum trees = Eucalyptus trees
Oil of eucalyptus = volatile terpene
Used in flavourings, cough drops, synthesis of menthol

Tree/forestry/plant biomass biorefinery concept



Plants for drugs & medicines



Ethnopharmacology

Plants are the major source of pharmaceuticals & medicinal bioactives

small-molecule drugs

Herbal remedies

Plant extracted medicines
- 25% of small-molecule drugs
- 80% of primary health care (WHO)
- digoxin, codeine, diosgenin, etc

Nutraceuticals
- health-promoting bioactives

Plants

Discovery & Innovation

Functional foods
- Plant derived bioactives
- stanols, sterols, xylitol, beta-glucan etc

enzymes

Phytochemical & metabolic engineering

Proteins

Plant-made pharmaceuticals (Pharming)

Ornamental Plants

The Flower Carrier

Diego Rivera

For you to look up……

Plants for smoking, snuff & chewing

Plants for alcohols

Plants for scents & perfumes

Economic Botany starts at home

You are surrounded by products & biomaterials derived from plants

Can you spot them?

Do you know what plant materials you use in your daily life?

- end

Legumes:
The Nitrogen Specialists

- **Free nitrogen gas (N_2) + lots of energy yields ammonia (NH3)**
- **Catalyzed by the enzyme, nitrogenase, produced by bacteria in root nodules.**
- **NH_3 attached to amino acids, to yield high-N amino acids, proteins, & plants**

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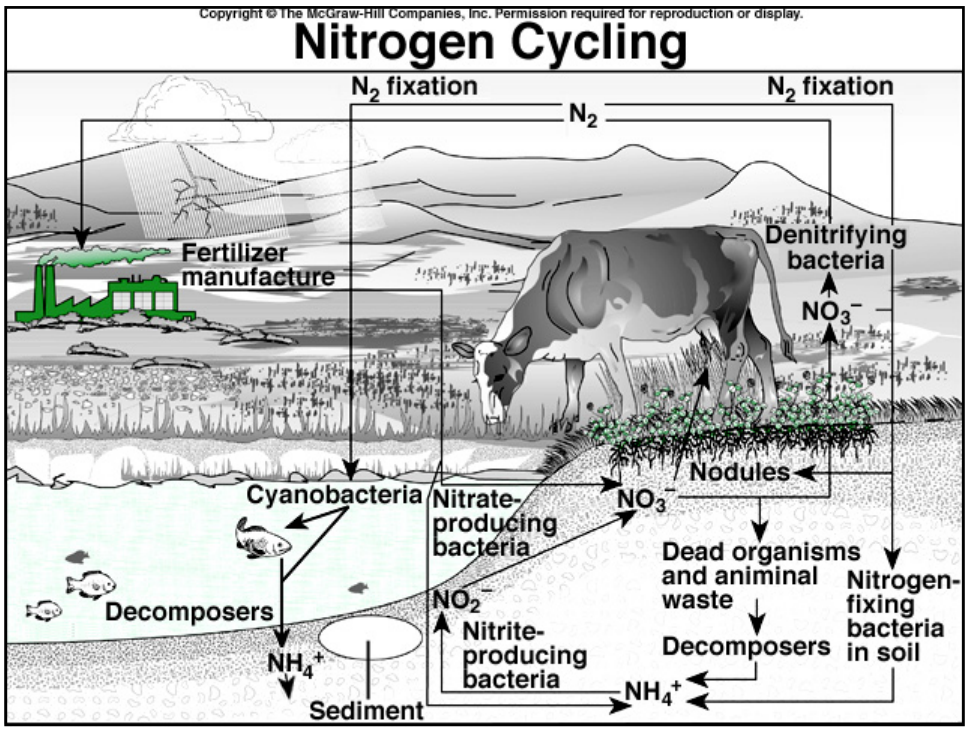

Nitrogen fixation

Nodules on white lupins

Nodules on white clover

Nodules ~ 1 mm wide.

red color due to leghaemoglobin.

- **Mutualism**
- **N-fixing bacteria (*e.g.*, *Rhizobium* species) infect roots of legumes & induce formation of specialized nodules**
- **Process relieves legumes of dependence on *available* forms of soil nitrogen**
  - **Ammonium, nitrate**
- **Correlates with 'high protein'**
  - **17-31%**

Legumes & nitrogen fertilizer

"Yard Long Beans" are growing on raised beds next to paddy rice in a traditional Sorjun farming system in Indonesia

- Energy intensive, from industrial process
- Haber-Bosch process
- With increasing fossil fuel costs, movement to grow more legumes
- Need to substitute fossil fuel derived nitrogen fertilisers